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TECHNICAL NOTES FRL-TN-20

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DETERMINATION OF SENSITIVITY TO IMPACT
OF PYROTECHNIC FLASH COMPOSITIONS USING
MODIFIED PICATINNY ARSENAL IMPACT TEST

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JUNE 1961



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MODIFIED PICATINNY ARSENAL IMPACT TEST**

by

**Joel Harris
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**Feltman Research Laboratories
Picatinny Arsenal
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Technical Notes FRL-TN-20

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Approved by:



**S. SAGE
Chief, Pyrotechnics
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OBJECT

To determine the impact sensitivity of selected pyrotechnic flash compositions at ambient and elevated temperatures, using the Picatinny Arsenal impact sensitivity apparatus.

To determine the effect of fuel particle size, composition aging, exposure to high relative humidity, and composition temperature on the impact sensitivity of these flash compositions.

SUMMARY

Run-down impact sensitivity tests were conducted on FP-790 (30/20/50 calcium/aluminum/potassium perchlorate), containing either elemental or calcium-carbonate-coated calcium and 60/40 potassium perchlorate/aluminum. The effects of fuel particle size, aging of the composition after blending, exposure of the composition to 75% relative humidity over various time intervals, and composition temperature were investigated.

Flash compositions containing calcium as fuel were found to be more impact sensitive than those containing atomized aluminum. In addition, the systems containing calcium exhibited the most marked increase in impact sensitivity on heating to 110°C.

No trend in impact sensitivity was apparent due to fuel particle size. The average particle sizes of the fuels investigated ranged from 4.4 to 28 microns for aluminum, and from 10.0 to 64.0 microns for calcium.

Aging of the compositions in sealed containers for one month resulted in a very slight increase in impact sensitivity, while exposure to 75% relative humidity caused a marked decrease in impact sensitivity.

The substitution of calcium-aluminum alloy for the individual fuel ingredients in FP 790 resulted in a slight increase in impact sensitivity. The use of calcium-carbonate-coated calcium in this composition did not appreciably affect its sensitivity as compared with elemental calcium.

INTRODUCTION

Premature detonations have occurred in several flash cartridges containing FP 790 (30/20/50 calcium/aluminum/potassium perchlorate) illuminant composition. Malfunctions of this type are not known to have occurred with 60/40 potassium perchlorate/aluminum composition. Accordingly, an evaluation of the sensitivity to impact of the above systems was undertaken in an effort to relate impact sensitivity to the setback forces incurred in launching flash cartridges containing these compositions.

The run-down impact test (Ref 1) consisted of first establishing a drop height where no ignitions were obtained. At each increased height (one-inch increments) 25 tests were performed and the number of

ignitions ('hits') and non-ignitions were noted. This continued until 25 ignitions out of 25 attempts were obtained. From these results, plots of the cumulative percentage of hits versus height in inches were made (Figs 3, 4, 5, pp 11, 12 and 13). The geometric means (50% points) obtained were taken as the measure of the sensitivity to impact of the systems. In addition, the sigma value (ratio of 84% to 16% level of ignition divided by 2) was calculated. This measure of the slope of the plotted data represented a measure of the rate of increase of sensitivity to impact. The range in inches from the zero ignition to the total ignition level was also recorded.

To determine the effects of varying fuel particle size on impact sensitivity, atomized aluminum fractions of average particle size 4.4, 14.5, and 28.0 microns and calcium fractions of average particle size 10.0, 36.0, and 64.0 microns were studied in the FP 790 and 60/40 systems. In addition, the effect of composition storage in sealed containers and exposure to a 75% relative humidity for periods of 7 hours and 7 days was studied.

In order to determine the temperature to which the FP 790 composition was raised on actual firing of a flash item, skin temperature measurements were made during the firing of a Clover cartridge stack (Ref 2). A skin temperature of 120°C was recorded, and heat transfer calculations were made which indicated a temperature of approximately 110°C within the cartridge. Run-down impact tests were then conducted on FP 790 mixes containing

either calcium-carbonate-coated or elemental calcium and a 60/40 potassium perchlorate/aluminum mix maintained at approximately 110°C, to determine the effect of this temperature level on their impact sensitivities.

Run-down impact tests were also conducted on a 60/40 potassium perchlorate/calcium composition for comparison purposes with the 60/40 system containing aluminum.

Friction sensitivity tests were run on all compositions evaluated to determine if any correlation existed between impact and friction sensitivity results.

RESULTS .

Table 1 (p 6) details run-down impact data for FP 790 composition as a function of fuel particle size, aging of the composition, exposure to 75% relative humidity over 7-hour and 7-day intervals and composition temperature. In addition, friction sensitivity data for all the systems investigated are given.

Table 2 (p 7) lists the above data for the 60/40 potassium perchlorate/aluminum system as well as impact and friction results for a single 60/40 potassium perchlorate/calcium mixture.

A comparison of run-down impact tests conducted at ambient temperatures and 110°C on FP 790 mixtures (containing either elemental or calcium-carbonate-coated calcium) and 60/40 potassium perchlorate/aluminum are given in Table 3 (p 8).

Figure 1 (p 9) is a temperature-time curve obtained in measuring the skin temperature of a Clover cartridge stack during firing.

Figure 2 (p 10) represents four temperature-time curves which indicate the heat loss of FP 790 composition in a Picatinny Arsenal Impact Test cup on removal from an oven, with subsequent exposure to room temperature. These curves were used in establishing a test temperature of 110°C in connection with conducting run-down impact tests at this temperature.

Figures 3, 4, and 5 (pp 11, 12, and 13) represent plots of the cumulative percentage of hits versus height in inches at both ambient temperature and 110°C for FP 790 (containing either elemental or calcium-carbonate-coated calcium) and 60/40 potassium perchlorate/aluminum.

DISCUSSION OF RESULTS

The FP 790 composition containing uncoated calcium showed the most marked increase in impact sensitivity, going from 26.0 inches at ambient to 18.2 inches at 110°C (Table 3, p 8). The composition containing calcium-carbonate-coated calcium showed a less marked increase in sensitivity (24.2 to 19.6 inches), while the 60/40 potassium perchlorate/aluminum exhibited the least proportional increase in sensitivity (35.5 to 30.5 inches). In addition, there was a marked decrease in both range and sigma value for the FP 790 systems at 110°C. The 60/40 potassium perchlorate/aluminum system,

however, showed no appreciable change in either range or sigma value on heating to the above temperature. The substitution of coated for elemental calcium in FP 790 did not appreciably affect friction sensitivity results (Table 1, p 6).

The results of run-down impact tests (Tables 1, 2, pp 6, 7) on three each FP 790 and 60/40 potassium perchlorate/aluminum compositions containing three particle size levels of calcium (10.00, 36.0, and 64.0 microns) and aluminum (4.4, 14.5, and 28.0 microns) revealed no trend due to the fuel particle size. Aging of these compositions in sealed containers for up to one month resulted in slight increases in impact sensitivity (Tables 1, 2), well within the experimental error of the test, when compared with results obtained with the fresh systems.

FP 790 composition containing 36-micron calcium, on exposure to a 75% relative humidity level for 7 hours, exhibited a 5-inch decrease in impact sensitivity. Thus, a trend was established between the formation of calcium hydroxide and decreased impact sensitivity of this mixture.

The substitution of calcium-aluminum alloy for the individual fuel ingredients in FP 790 resulted in no appreciable change in either impact or friction sensitivity (Table 1). The substitution of silver-doped potassium perchlorate for potassium perchlorate in the 60/40 potassium perchlorate/aluminum system resulted in a slight increase (35.5 to 33.0 inches) in impact sensitivity (Table 2).

Impact results obtained for the 60/40 potassium perchlorate/calcium system (Table 2, p 7) established this mixture as the most sensitive of all the systems tested (18.0 inches), and further confirmed the increased impact sensitivity of calcium as compared with aluminum.

CONCLUSIONS

1. Flash compositions containing calcium as fuel are more sensitive to impact than those containing aluminum. The calcium-containing systems showed the most marked increase in impact sensitivity on heating to 110°C. Assuming a relationship between impact sensitivity and setback forces, it is apparent that calcium-containing compositions would be more sensitive to setback forces than those containing aluminum.

2. No meaningful trend in impact sensitivity was apparent resulting from fuel particle size, aging of the compositions after blending, substitution of calcium/aluminum alloy for the individual fuel ingredients, or substitution of calcium-carbonate-coated calcium for elemental calcium.

3. Exposure of calcium-containing flash compositions to high relative humidities results in a decrease in impact sensitivity.

EXPERIMENTAL PROCEDURE

In order to approximate the temperature to which the flash mixture was raised during the firing of a Clover cartridge stack, skin temperature measurements were made. A thermocouple was placed on the outer wall of the fourth cartridge to ascertain skin temperature, since premature detonations involving the Clover cartridge stack were reported to have occurred with

the ignition of the fourth cartridge. The temperature-time curve shown in Figure 1 (p 9) was obtained during the firing of a Clover stack. A 32 gauge chromel-alumel thermocouple, utilizing a Mosley model 3XY recorder equipped with time base, was used to obtain this curve.

The first three maxima of the curve in Figure 1 represent the temperatures recorded on the wall of the fourth cartridge by the thermocouple due to the firing of the first three cartridges of the Clover stack. The fourth rise represents the skin temperature of the fourth cartridge on firing while the fifth maximum is caused by the heat of the burning propellant charge of the fifth cartridge on passing the now detached thermocouple wire. A temperature of approximately 120°C was recorded as the maximum temperature of the outer wall of the fourth cartridge prior to its expulsion. A ten-degree temperature gradient was calculated between the outer and inner walls of the cartridge. In order to approximate the temperature of the flash composition in contact with the cartridge inner wall, the assumption was made that the temperature recorded for the fourth rise in Figure 1 penetrated 0.5 mm into the cartridge wall. Any deviation from this amount of heat penetration would not cause the temperature gradient to change by more than a few degrees. Based on the further assumption that the flash powder in contact with the cartridge inner wall would rise to approximate the temperature of the inner wall because of its much smaller mass, the run-down impact tests at elevated temperature described earlier in this report were conducted at 110°C.

Procedures followed for conducting the run-down impact tests are similar to those described in Reference 3. The statistical design of the test is outlined in Reference 1 under procedures for run-down test.

MATERIAL USED

1. Calcium, atomized, Valley Metallurgical Processing Co., Inc. Average particle diameter: 10, 36, and 64 microns.

2. Aluminum, atomized, Specification MIL-P-14067, Allied Chemical Co. Average particle diameter: 4.4, 14.5, and 28 microns.

3. Potassium perchlorate, Specification PC-PD-254, Western Electro Chemical Co. Average particle diameter: 22 microns.

4. Calcium, atomized, coated with calcium carbonate, prepared at Picatinny Arsenal. Average particle size: 64 microns.

5. Calcium/aluminum alloy, Valley Metallurgical Processing Co., Inc. Average particle size: 41 microns.

REFERENCES

1. Bulfinch, A. *Improved Methods and Techniques for Testing Impact Sensitivity of Explosives*, Picatinny Arsenal Technical Report 2282, July 1958
2. 'Clover' Photoflash Cartridge, Dwg. No. FXP-94572 (1 May 1959)
3. Clear, A. J., *Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives*, Picatinny Arsenal Technical Report 1401, Feb 1950

TABLE 1
Run-down impact and friction sensitivity data for FP-790 composition*

Particle Size of Calcium, microns	Temperature of Impact Test, °C	Relative Humidity, %	Date Blend Prepared	Date of Impact Test	Impact Test Results				Friction Pendulum Test	
					50% Point, in.	Sigma Value	Minima, in.	Maxima, in.	Steel Shoe	Fiber Shoe
10	Ambient	Ambient	2/3/60	2/8/60	25.0	0.64	18	29	Complete detonation	No action
36	"	"	"	2/9/60	26.0	0.71	15	32	"	"
64	"	"	"	2/10/60	23.5	0.70	15	29	"	"
10	"	"	"	2/29/60	23.8	0.62	17	27	"	"
36	"	"	"	3/1/60	21.5	0.66	11	25	"	"
64	"	"	"	3/2/60	24.0	0.71	12	30	"	"
36	"	75 (7 hr)	"	3/25/60	30.0	0.59	22	33	"	"
36	"	75 (7 days)	"	3/31/60	40.0	0.61	30	45+	"	"
36-64**	"	Ambient	"	4/11/60	24.2	0.64	18	28	Complete burning	"
36	110	"	5/9/60	5/10/60	18.2	0.60	14	20	-	-
36-64**	110	"	"	5/12/60	19.6	0.60	15	22	-	-
41***	Ambient	"	"	4/28/60	21.4	0.70	13	26	Complete detonation	No action

FP-790	Percentage Composition	Particle Size, micron
Calcium	30	See column 1 above
Aluminum	20	14.5
Potassium perchlorate	50	22.0

** Calcium containing a surface coating of calcium carbonate

*** Calcium/aluminum alloy substituted for individual ingredients.

TABLE 2
Run-down impact and friction sensitivity data for 60/40 potassium perchlorate/aluminum composition*

Particle Size of Aluminum, microns	Temperature of Impact Test, °C	Date Blend Prepared	Date of Impact Test	Impact Test Results				Friction Pendulum Test	
				50% Point, in.	Sigma Value	Range of Impact Values		Steel Shoe	Fiber Shoe
						Minima, in.	Maxima, in.		
60/40 Potassium Perchlorate (22 microns)/Aluminum									
4.4	Ambient	2/3/60	2/5/60	35.0	0.63	24	40+	Complete Detonation	No action
14.5	"	"	2/11/60	35.5	0.63	25	40+	"	"
28.0	"	"	2/12/60	32.0	0.65	20	37	"	"
14.5	"	"	3/17/60	34.0	0.66	24	40+	"	"
14.5**	"	3/28/60	4/27/60	33.0	0.63	22	36	"	"
14.5	110°	5/9/60	5/13/60	30.5	0.63	21	36	"	"
60/40 Potassium Perchlorate/Calcium*									
Ambient		3/28/60	4/29/60	18.0	0.60	14	20	"	"

*A 60/40 potassium perchlorate/calcium composition was included in the tests for comparison purposes. The particle sizes of these materials were 22 and 36 microns, respectively.

**Silver-perchlorate-doped potassium perchlorate substituted for potassium perchlorate.

TABLE 3
Comparison of ambient and heated run-down impact tests

Composition	Percentage Composition	Particle Size, microns	Temp, °C	Range of Impact Values					
				84% Point, in.	16% Point, in.	50% Point, in.	Sigma Value	Minima, in.	Maxima, in.
Calcium	30	36	Ambient	30.0	21.0	26.0	0.72	15	32
Aluminum	20	15							
Potassium perchlorate	50	22	110°C	19.8	16.6	18.2	0.60	14	20
Calcium-carbonate-coated calcium	30	64	Ambient	27	21.0	24.2	0.64	18	28
Aluminum	20	15	110°C	21	17.7	19.6	0.60	14	22
Potassium perchlorate	50	22							
Aluminum	40	15	Ambient	39	31	35.5	0.63	25	40+
Potassium perchlorate	60	22	110°C	34	26	30.5	0.66	21	36

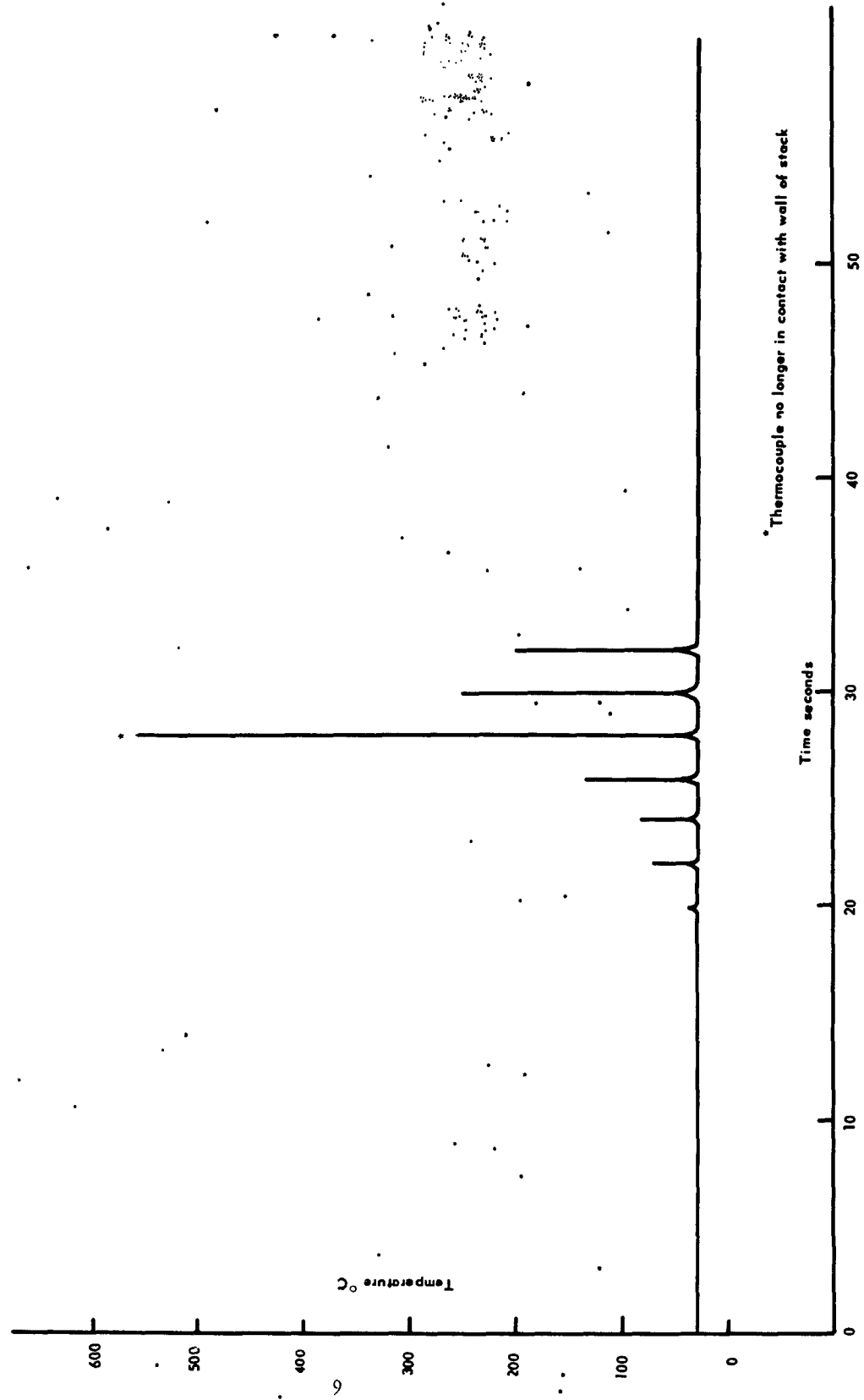
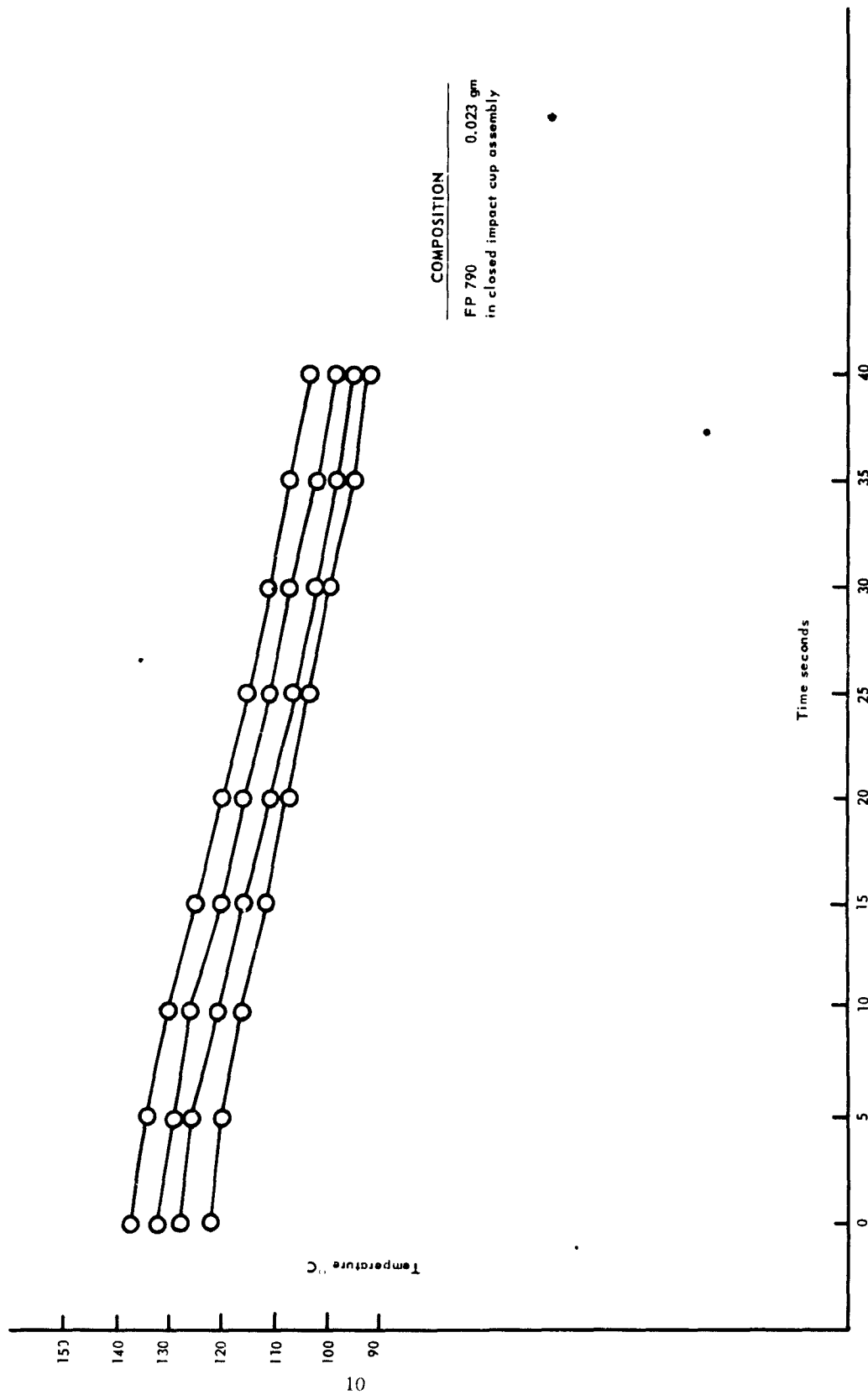


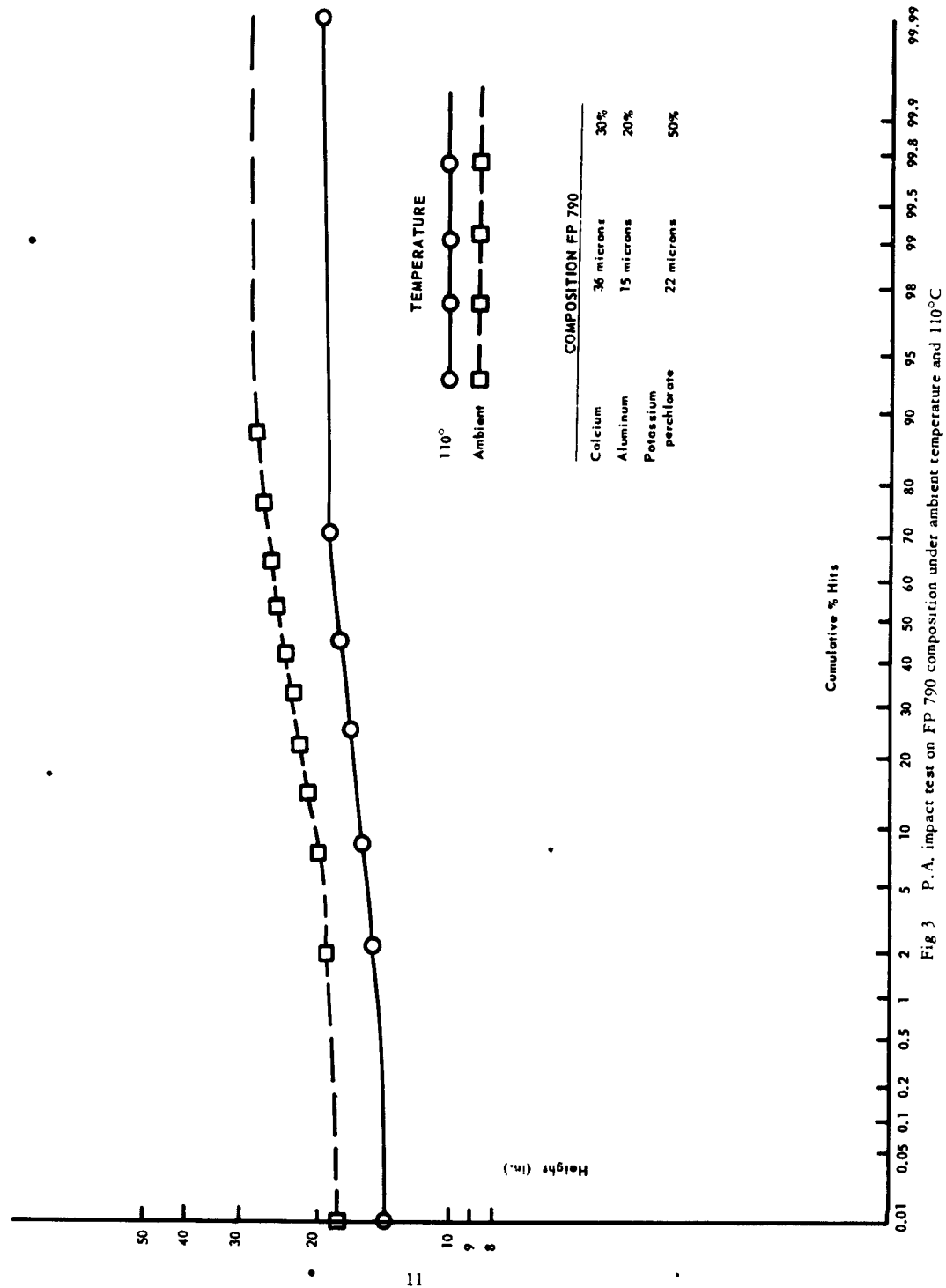
Fig 1 Temperature-time curve of Clover stack firing



COMPOSITION

FP 790 0.023 gm
in closed impact cup assembly

Fig 2 Heat loss vs time of FP 790 composition in P.A. impact test cup on exposure to room temperature



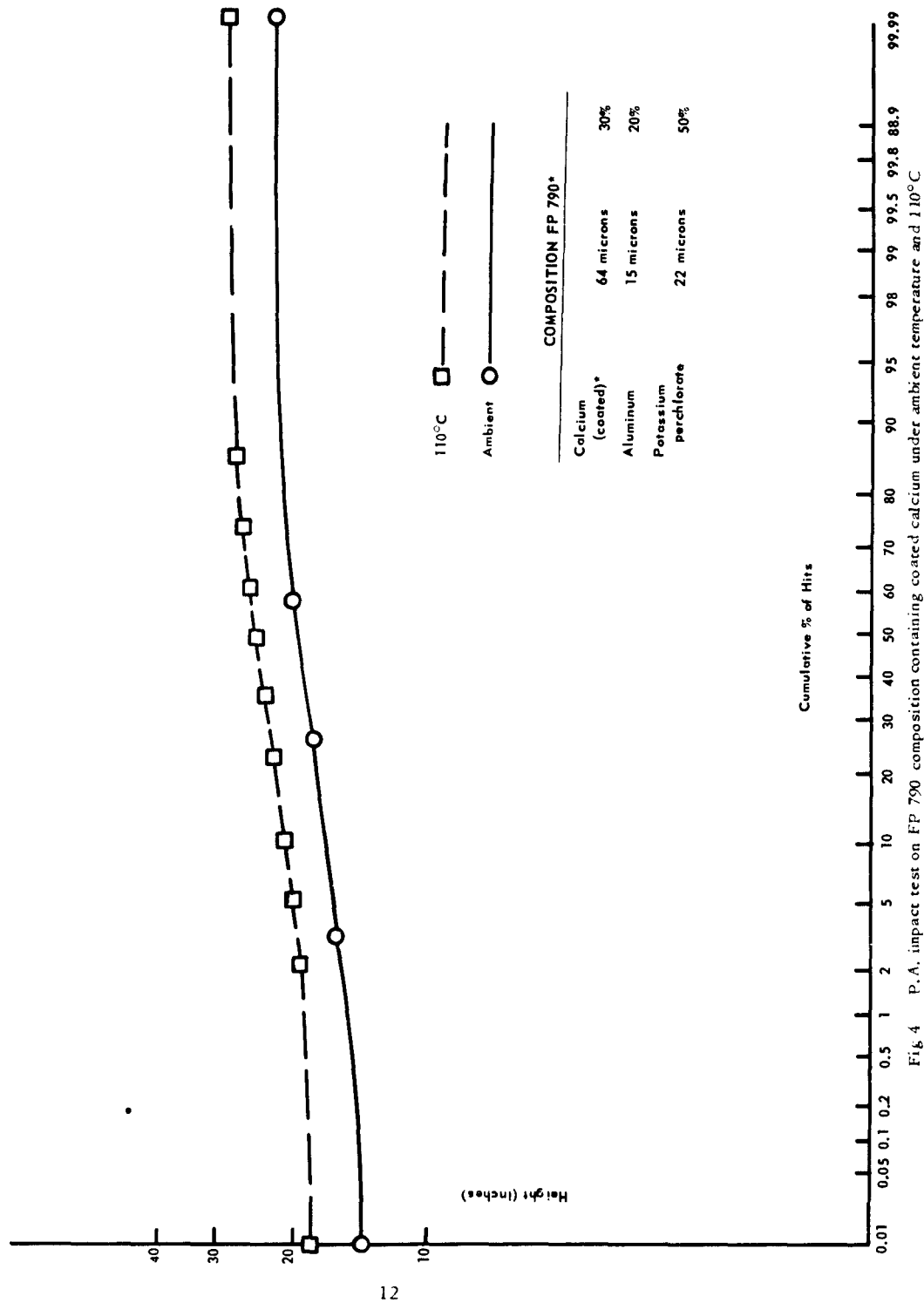
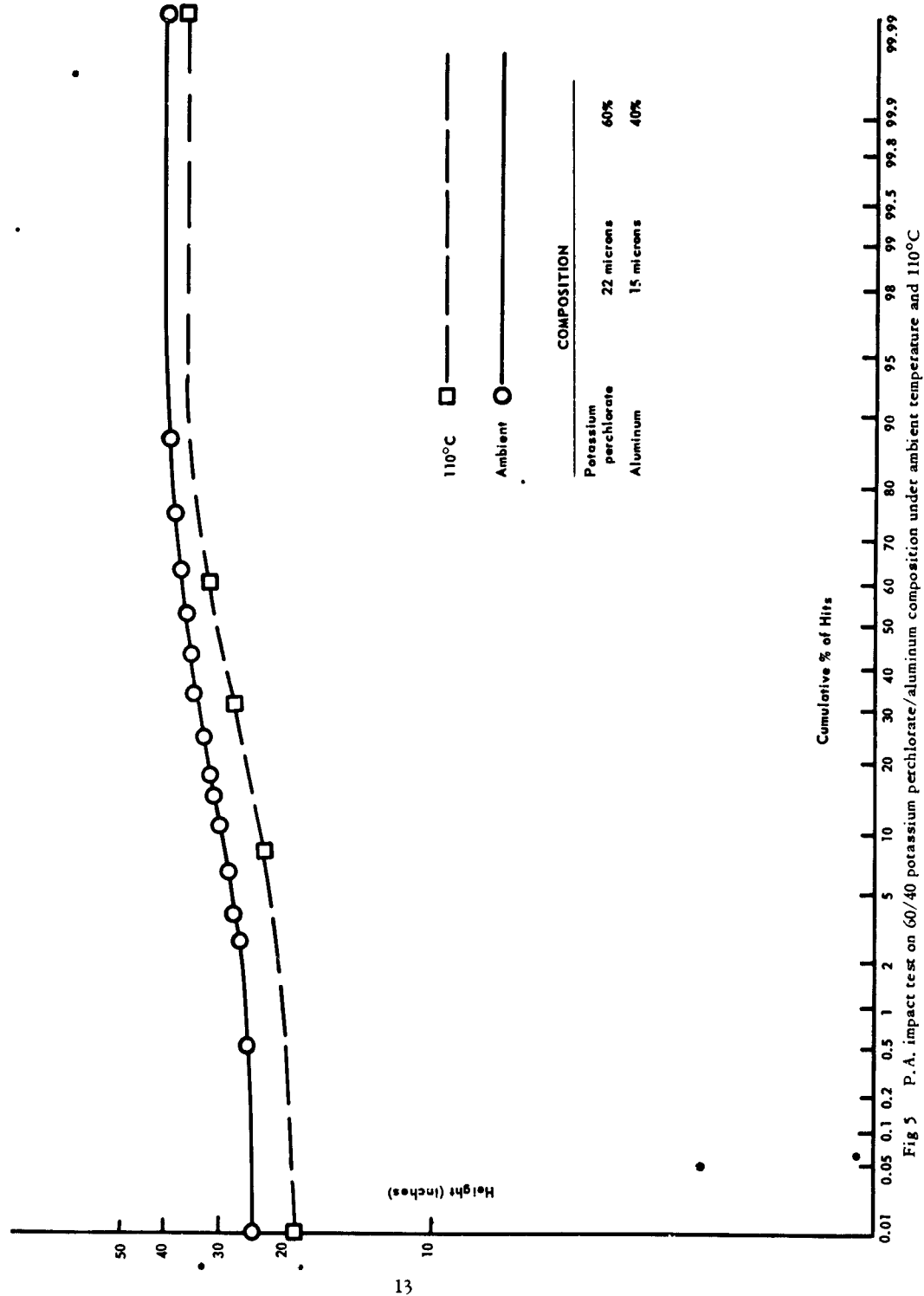


Fig 4 P.A. impact test on FP 790 composition containing coated calcium under ambient temperature and 110°C



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2. Calcium - Combustion
3. Aluminized explosives - Sensitivity

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